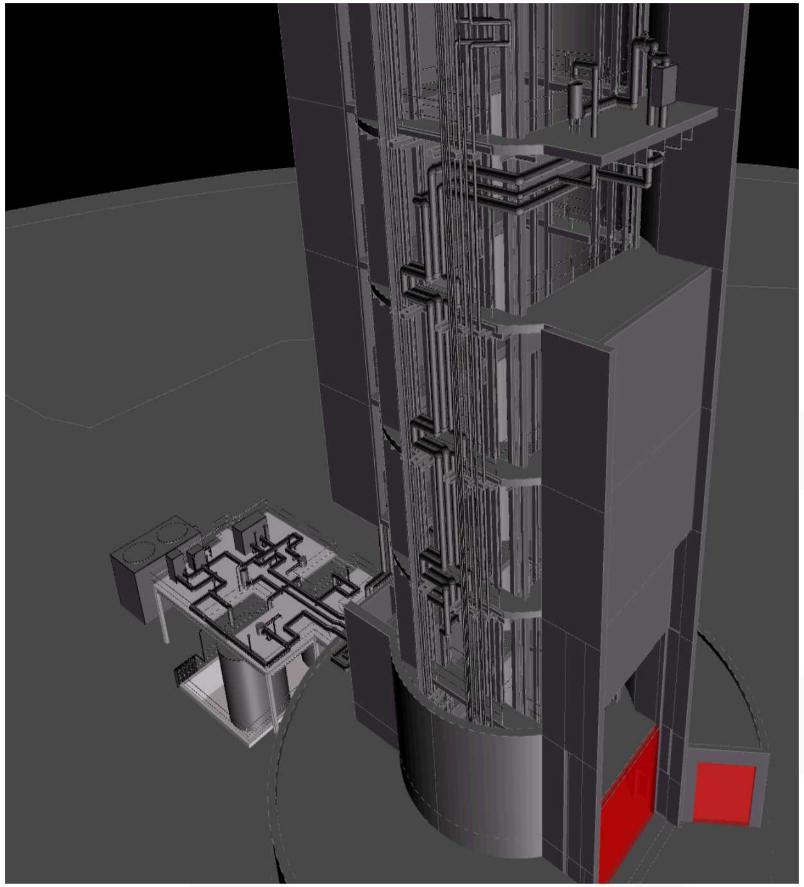
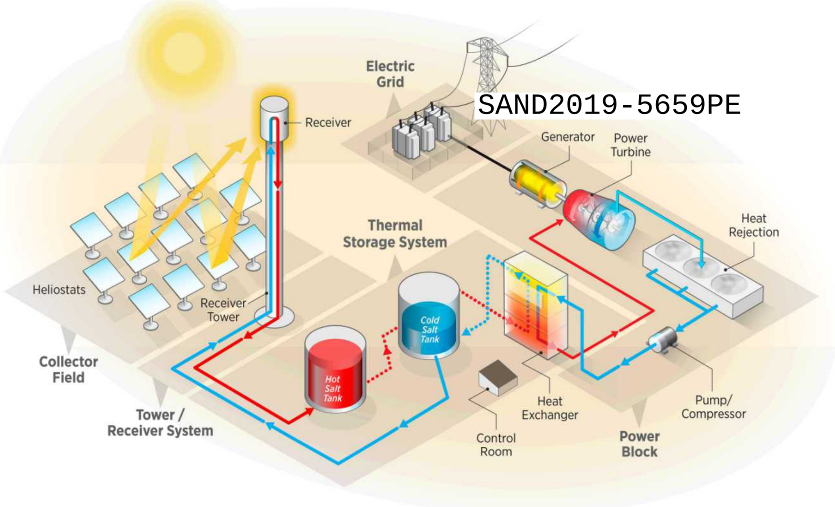
SOLAR ENERGY
TECHNOLOGIES OFFICE
U.S. Department Of Energy





SAND2019-5659PE

Gen 3 Pumps & Valves WebEx

Gen3 Liquid-Pathway Topic 1 & Topic 2 Teams

5-23-2019

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy?s National Nuclear Security Administration under contract DE-NA0003525.

Contents


Gen3CSP
Bringing together the people and the pieces for an
INTEGRATED CSP SYSTEM

Gen3 Liquid Pathway

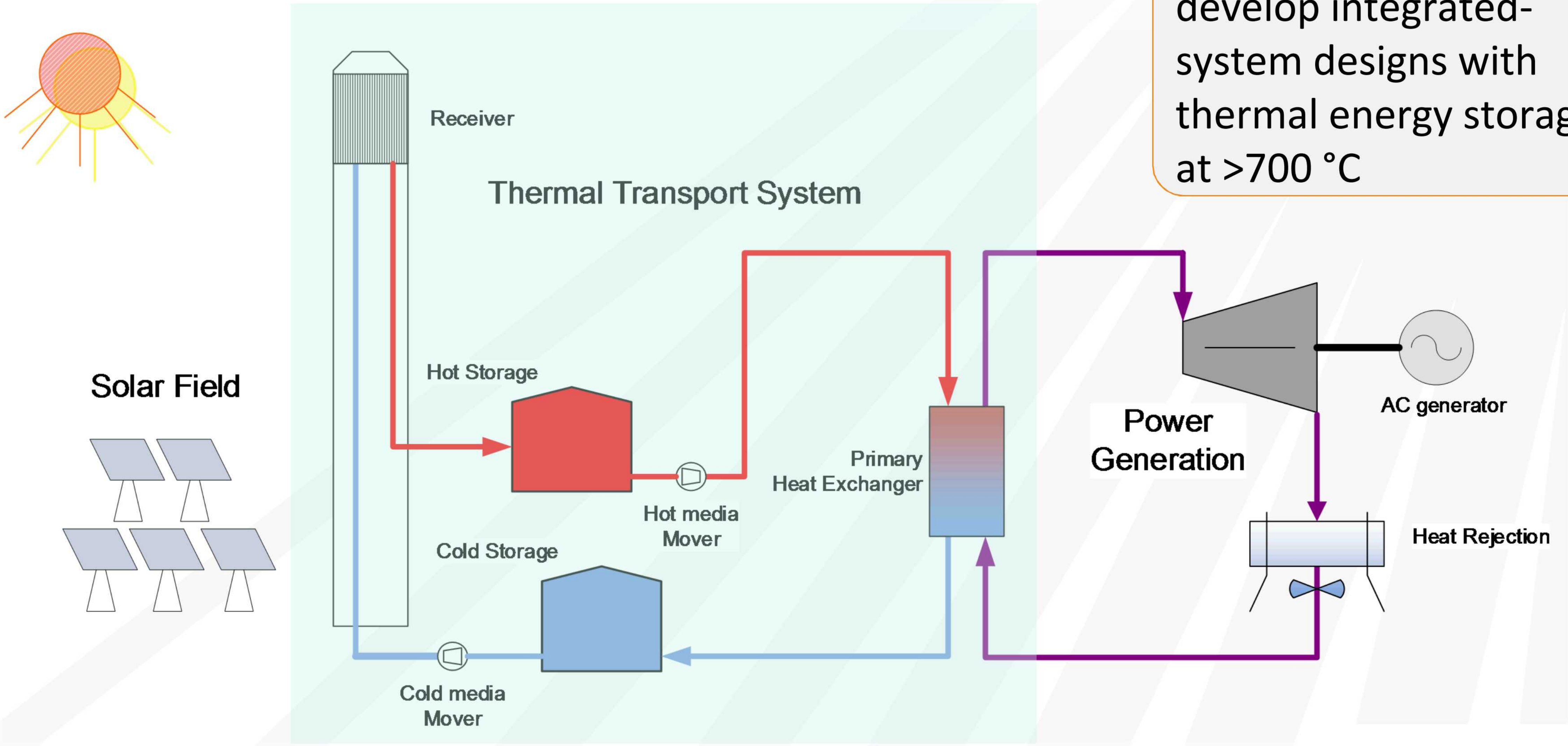
- Leverage expertise with liquid-HTF towers
- Examine two, alternative high-temp liquids
- Use low-cost, thermally stable energy storage media
- Design for sCO_2 Brayton-cycle integration

Vast Solar Jemalong
Sodium-HTF pilot facility (Australia)

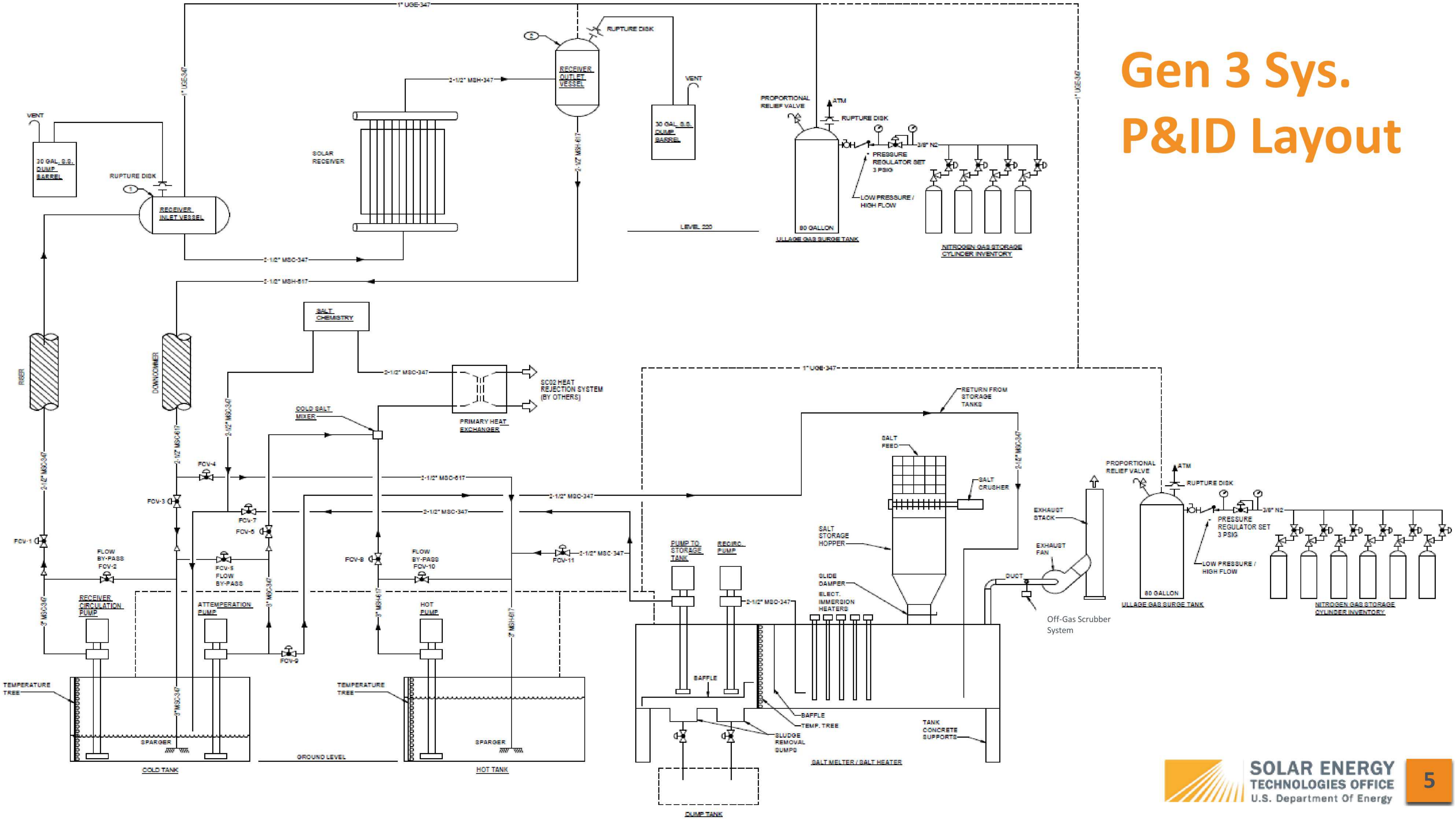
SolarReserve Crescent Dunes
Molten-salt HTF plant (USA)

Gen3 Program addresses the Thermal Transport System

Goal:
De-risk high-temp components and develop integrated-system designs with thermal energy storage at >700 °C



Gen 3 Sys. P&ID Layout



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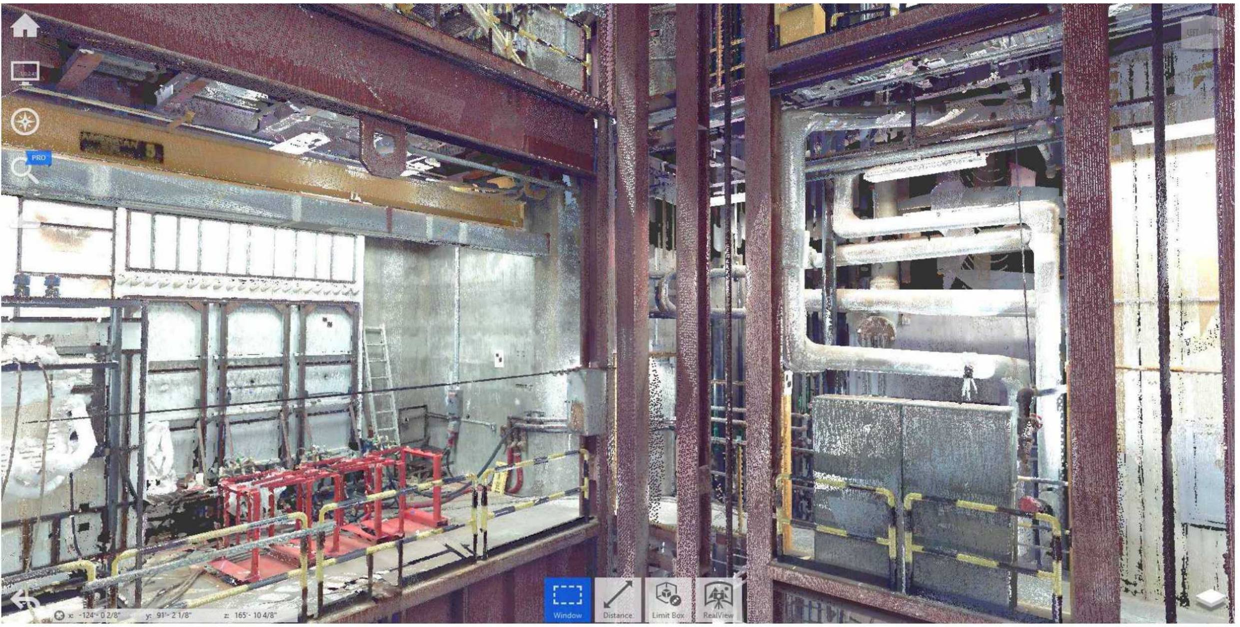
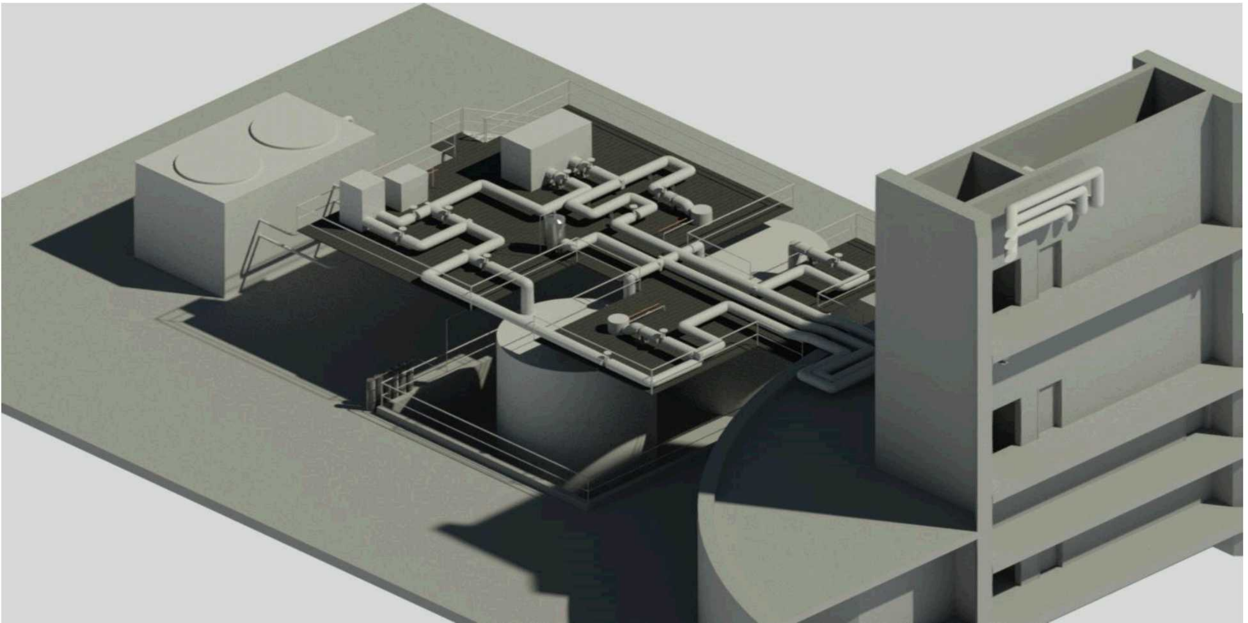
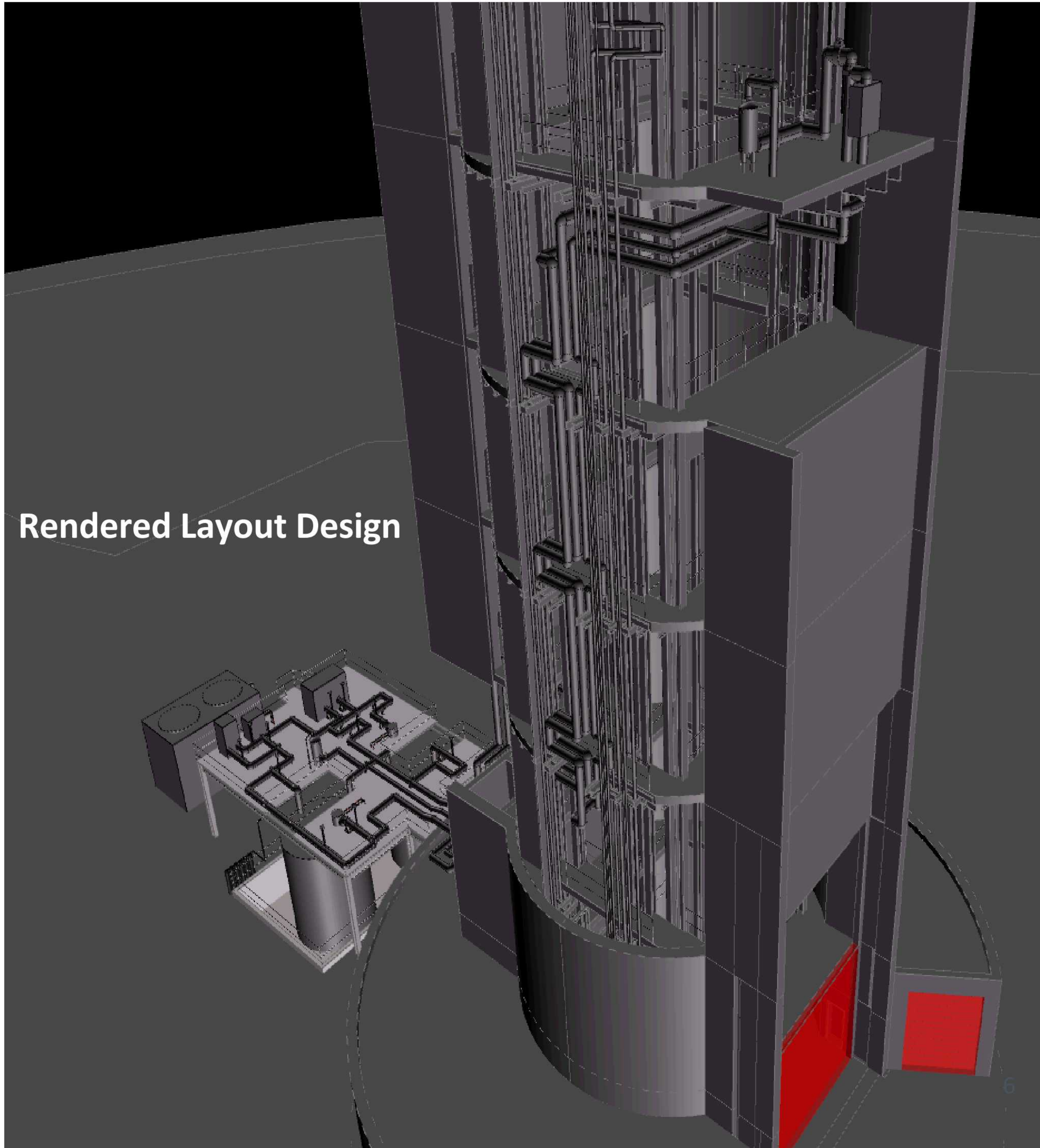
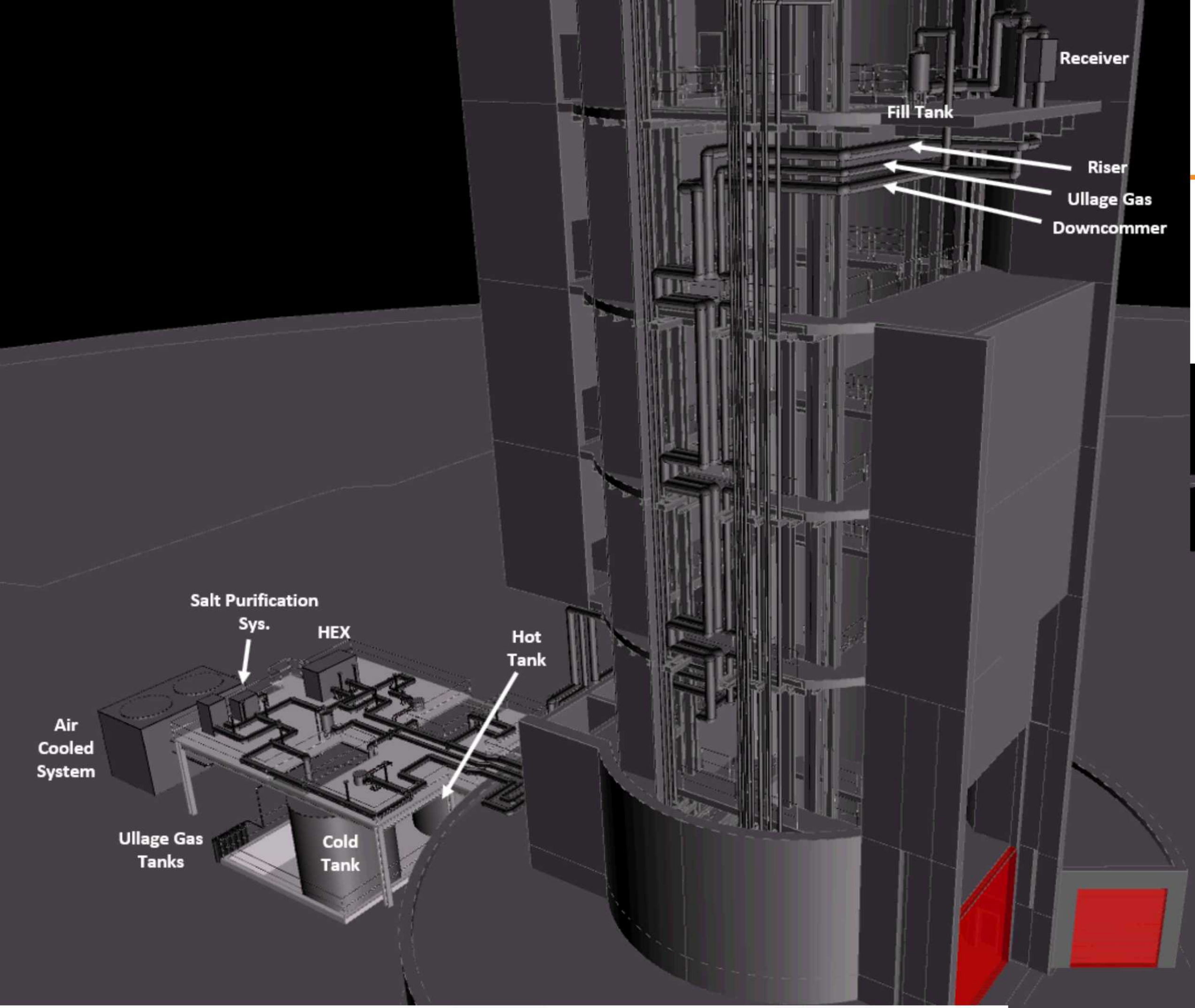
220 ft Point Cloud Tower Level

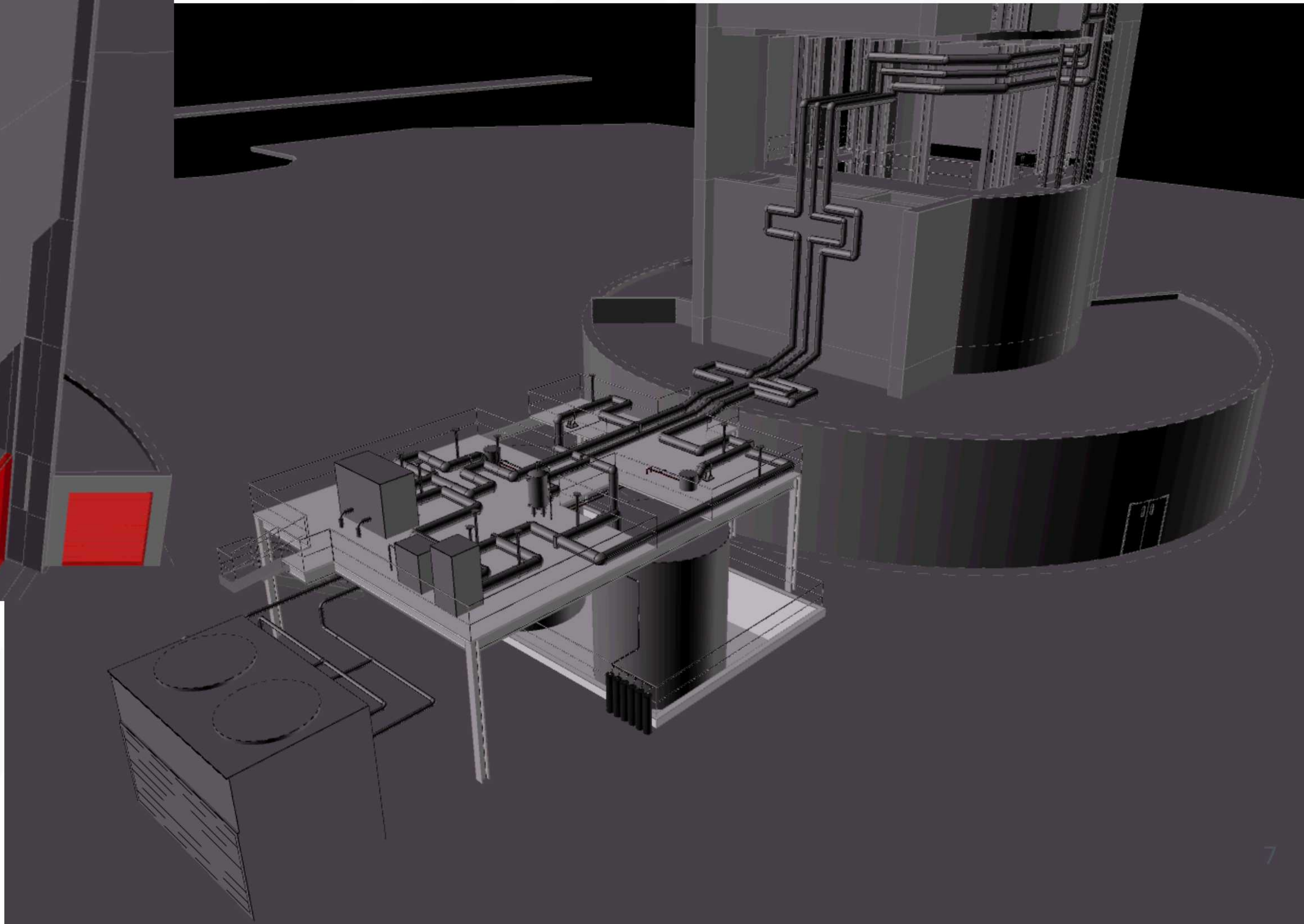


Rendered Revit 3D Model




Rendered Layout Design


Receiver
Fill Tank
Riser
Ullage Gas
Downcommer
Salt Purification Sys.
HEX
Hot Tank
Air Cooled System
Ullage Gas Tanks
Cold Tank



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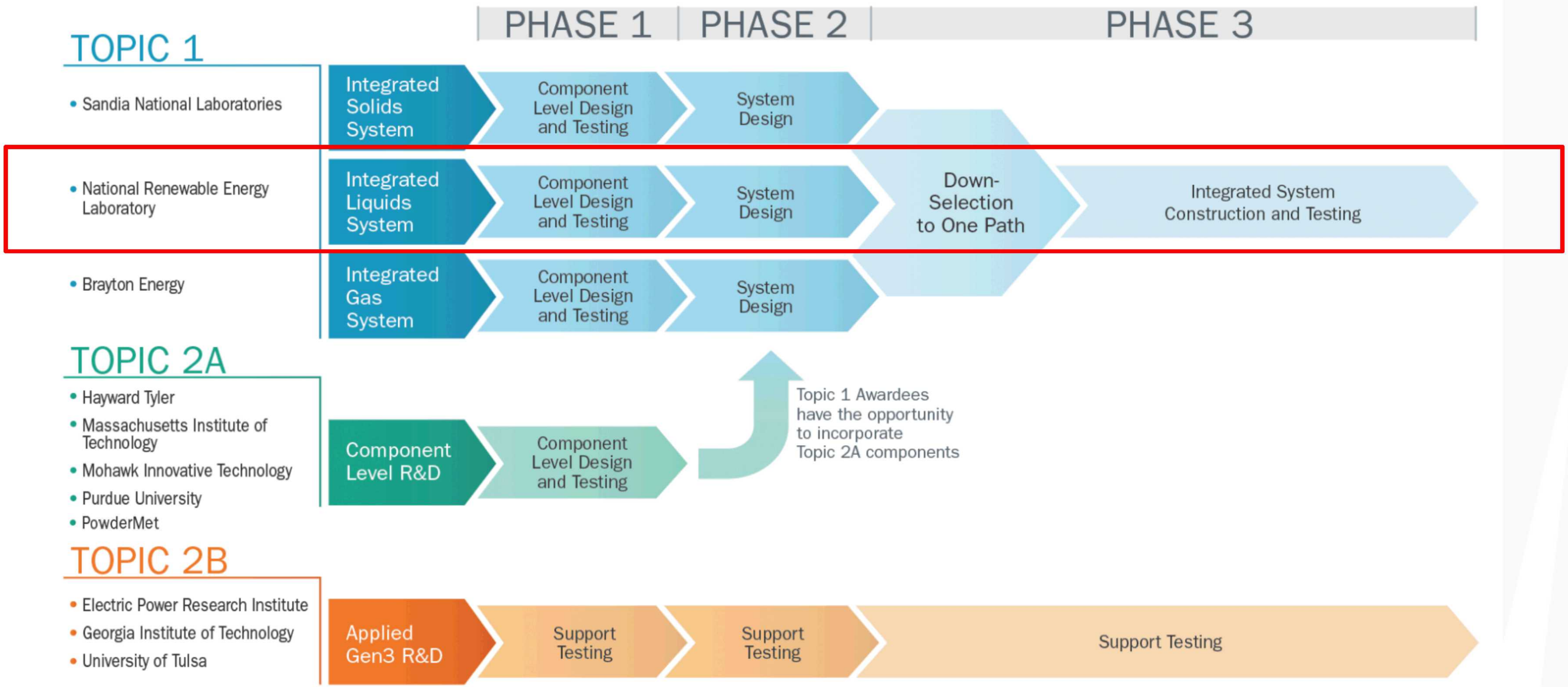
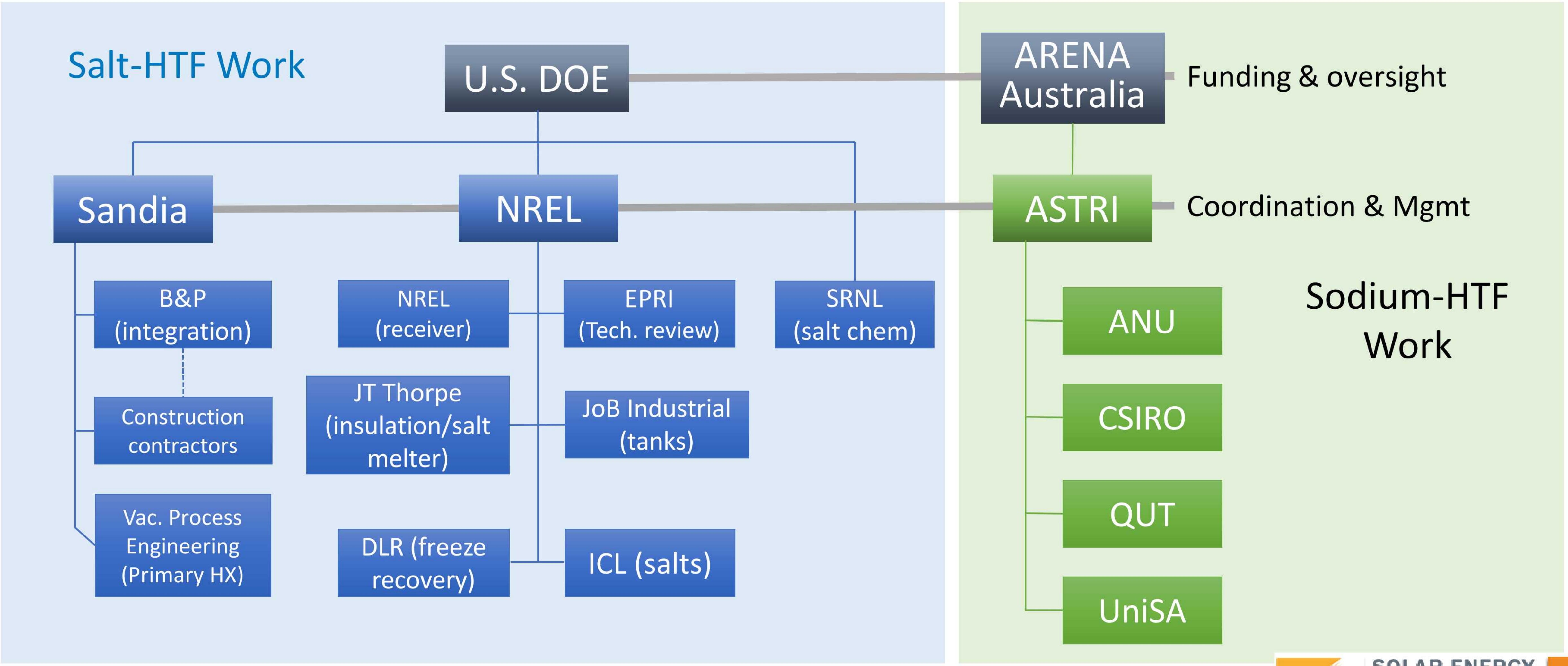
Gen3CSP
Bringing together the people and the pieces for an
INTEGRATED CSP SYSTEM

DOE CSP Gen3 Program



U.S. Department of Energy, https://www.energy.gov/eere/solar/generation-3-concentrating-solar-power-systems-gen3-csp

Introductions – Topic 1 Partners



High-Temperature System Designs – Dan Barth

- Dan Barth & High-Temperature System Designs tasked as Gen 3 Consultant

- HTSD is tasked with supporting development of Gen 3 molten salt pumps and valves for both Topic 1 & 2 teams

- Dan is also responsible for supporting integration of pumps and valves with full-scale Pilot-system, which includes P&ID development with B&P.

Topic 2 Pump & Valve Teams (1-2 Min. Overviews)

Teams

- Massachusetts Institute of Technology and Flowserve: (2 Awards)
  ~ Ceramic Castable Cement Tanks and Piping for Molten Salt

  The development of ceramic castable cements for thermal storage tanks and piping to resist corrosion and penetration by the high temperature chloride salts.

  ~ High-Temperature Pumps and Valves for Molten Salt

  This project will develop high-temperature low-cost ceramic-metal composite materials for pump and valve components used in 750 C chloride salts.

- Hayward Tyler and ORNL:
  ~ Development of High Temperature Molten Salt Pump Technology for Gen 3 Solar Power Tower Systems

  Hayward Tyler will seek to improve existing long-shafted pump technology of the radial bearings and sleeves in both materials and designs to provide lower costs and longer life cycles of the hot and cold pumps.

- Powdermet, Sulzer Pumps and University of Madison Wisconsin:
  ~ High-Toughness Cermets for Molten Salt Pumps

  This team will develop a ceramic-metal composite material (Cermet) resistant to the poor lubrication during dry running conditions of the startup and shut down modes of operation, corrosion and erosion caused by the Chloride salts and insolubles.

Topic 2 Pump & Valve Teams

Support:

- Kevin Robb (ORNL) – PI for 300-kWth chloride salt test loop

  This project focuses on the design, construction, and operation of a lab-scale test Facility to Alleviate Salt Technology Risks (FASTR). FASTR is a versatile high-temperature molten chloride salt facility designed for temperatures greater than 700 °C and for a variety of testing in support of the Gen3 CSP molten salt pathway. FASTR and the accompanying research will provide the foundational capabilities necessary to support Gen3 CSP awardees.

- Dan Barth (High Temperature System Designs, LLC)

  High Temperature System Designs, LLC is a consultant to the Topic 1 team and will share lessons learned from years of experience working with major OEM pump manufactures, major engineering firms, universities, national labs and private industry on molten salt applications. Reducing RISKS associated with molten salt systems and reducing costs of new designs and technology in order for these technologies to be commercialized will be HTSD, LLC primary objective working with the Topic 2 Teams.

Contents


Gen3CSP
Bringing together the people and the pieces for an INTEGRATED CSP SYSTEM

3-Phase Project (Spanning five years)

Phase 1

- Validate properties
- Select materials
- Design and test critical components
- Month 1-18

Phase 2

- Select between salt and sodium
- Propose integrated system design
- Month 19-24

DOE review and pathway selection

Phase 3

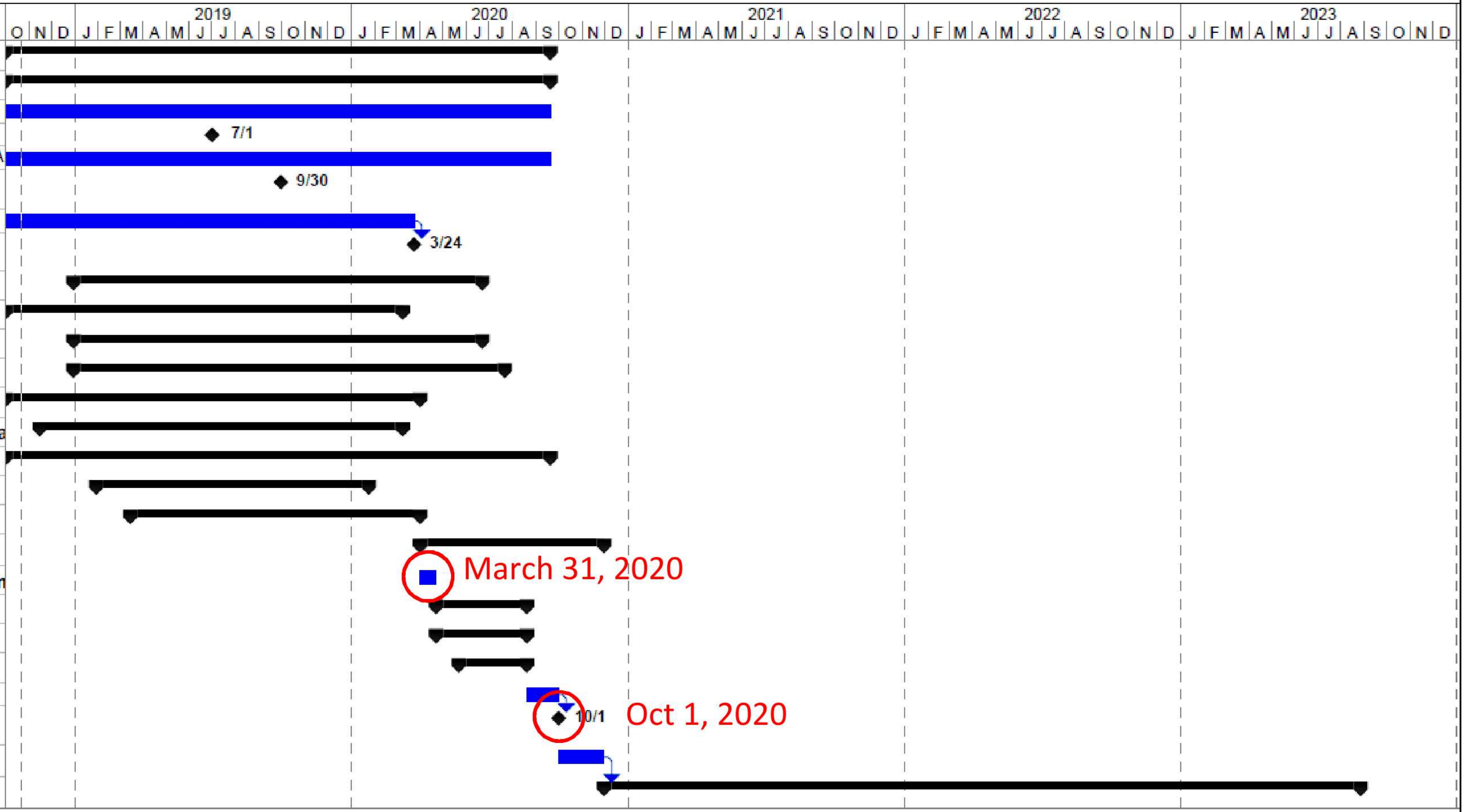
- Construction
- Test
- Document

Phase Schedule

FOA Number: DE-FOA-0001697
Project Title: Liquid Pathway to SunShot
Version Date: 5/28/2018

Organization: NREL
Point of Contact: Craig Turchi
Email: craig.turchi@nrel.gov
Phone: 303-384-7565

ID	SOPO Item	Item Description	Performer
1	T-1.0	**Project Management - Phase 1-2**	**NREL**
9	T-1.1	**Materials Characterization & Selection**	**NREL, SRNL**
10	ST-1.1.1	Alloy compatibility and selection	NREL, QUT
11	M (ST-1.1.1)	Alloy options and recommendations	NREL
12	ST-1.1.2	Salt chemistry and corrosion control	NREL, SRNL, UniSA
13	M (ST-1.1.2)	Chloride-salt properties defined for system design	NREL
14	ST-1.1.3	Refractory insulation compatibility and selection	NREL, JTT
15	M (ST-1.1.3)	Refractory selected and properties defined	NREL
16	T-1.2	**Pump & Valve Design**	
21	T-1.3	**Piping and Heat Trace**	**Sandia, B&P**
29	T-1.4	**Tank Design**	**Brahma, NREL**
34	T-1.5	**Primary HX design**	**Sandia/VPE**
39	T-1.6	**Storage Options for Sodium**	**ANU, UniSA**
46	T-1.7	**Salt Receiver Design**	**NREL, SR, Sandia**
52	T-1.8	**Sodium Receiver Design**	**ANU, CSIRO**
59	T-1.9	**Freeze Mitigation & Recovery**	**DLR**
62	T-1.10	**System Simulation & Cost Estimation**	**NREL, CSIRO**
66		**Phase 2 - System Design**	
67	T-2.1	**Design review and downselect**	**Leadership team**
68	T-2.2	**Component Design Packages**	
75	T-2.3	**System Design Package**	
79	T-2.4	**Simulation and Cost Analysis**	
81		Proposal Red Team Review & Revision	
82	M (T-2.4)	Phase 3 proposal package submitted to DOE	NREL
83	G/NG-2	**Review of Phase 3 Proposal**	**DOE**
84		**Phase 3 - Fabrication & Test**	



Contents


Gen3CSP
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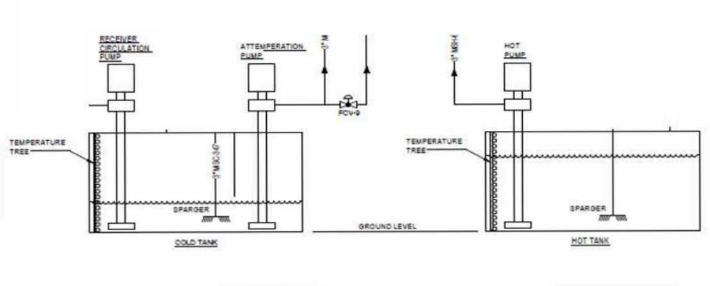
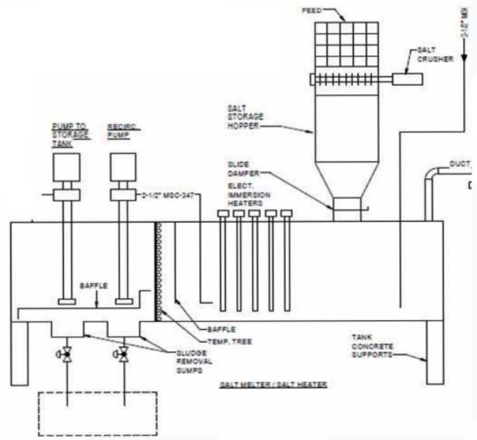
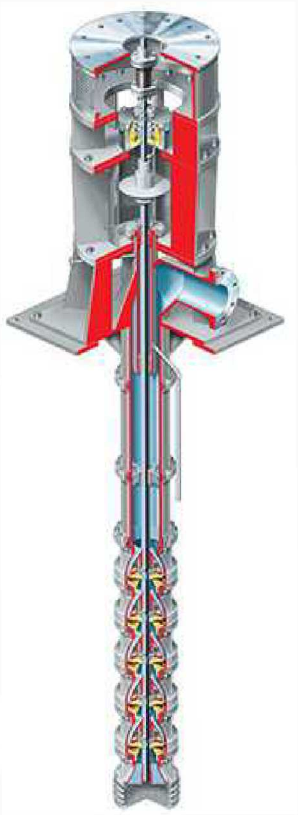
Gen 3 System – Pump Technical Challenges

- The Pumps required for the pilot plant will be:
  - ➢ Cold Salt Recirculation Pump
  - ➢ Hot Steam Generation Pump
  - ➢ Attemperation pump
- Overview of Pump Specifications – ***See Document***







Traditional Long-Shafted Pump Design, Courtesy of Flowserve

Gen 3 System – Pump Technical Challenges (Dan Barth)

- Material Selection for wetted components such as Volute, Impeller, Shafting, Column
- Pump sole plate and tank seal
- Column attachment to Pump mounting plate and heat shield
- Capability to reduce Heat dissipation up the shaft assembly to Thrust bearing
- Capability of Sealing the cover gas from the salt tanks (Possible HCl)
- Pump sizing because of low flow requirements (If recirculation is req.)
- Minimum submergence
- NPSHr
- Minimum distance of bottom of tank and from side walls
- Identifying natural frequencies of pump and mounting structure
- Must be capable of replacing Thrust Bearing without pulling pump
- Capability to adjust impeller when pump is hot
- Capability to monitor thrust bearing temperatures
- All fasteners below mounting must be locked to prevent loosening during operation
- Pumps must be capable of 100% self-draining during removal from hot salt
- Pump must be capable to operate at shut off for short periods if a freeze-up in the system occurs

Pump Technical Challenges (Risk Registry)

Aspect	Failure Mode	Probability (0.0-1.0)	Impact (0-5)	Risk score	Comments and Consequenses	Miletone?	Aspe ct	Aspect	Failure Mode
Shaft	Unstable	0.5	4	2.0	Bent shaft, too much wear in radial bearings,		2	Shaft	Unstable
Tank sparger system	Forces against pump	0.4	5	2.0	Critical		****	Tank sparger system	Forces against pump
Motor	Overheats	0.3	5	1.5	Locked rotor, loss of bearing clearance, Radial Bearing failure, freeze up in column, pump at Runout con		1	Motor	Overheats
Motor	Reverse rotation from back flow from system	0.3	5	1.5	Sytsem back flow can cause reverse rotation, restating pump could break shaft		**	Motor	Reverse rotation from back flow from system
Radial Bearings/	Insufficient lubricity/overheat	0.3	5	1.5	Radial bearing failure		3**	Radial Bearings/	Insufficient lubricity/overheat
Main mounting plate seals	Leak	0.3	5	1.5	Vertical turbine designs couldleak		3**	Main mounting plate seals	Leak
Main mounting plate/seals	Incompatible with salt/corrosion/ salt buildup	0.3	5	1.5	Seal failure		3**	Main mounting plate/seals	Incompatible with salt/corrosion/ salt buildup
Bearings/seals	Insufficient strength at operating temperature	0.3	5	1.5	Seal must be protected from heat/ thrust bearing must be protected from migation of heat up shaft		3	Bearings/seals	Insufficient strength at operating temperature
Flow	Over pressure	0.3	5	1.5	Freeeze up in sysytem, major problem in vertical turbine designed pumps for main seal		***	Insolubles in melted salt	High wear in bearings
Valve heat tracing		0.3	5	1.5	Critical		**	Flow	Over pressure
Insulation		0.3	5	1.5	Critical		***	Valve heat tracing	
Shaft Harmonic	High Vibration	0.3	4	1.2	High Vibration during startup or shut down, passing through critical speed		***	Insulation	
Shaft Sleeve for Raidal bearing	Incompatible with salt/corrosion	0.3	4	1.2	Surface finish will be damaged causing bearing failures		**	Shaft Harmonic	High Vibration
Bushings for radial sleeve	Incompatible with salt/corrosion	0.3	4	1.2	Surface finish will be damaged causing bearing failures		**	Shaft Sleeve for Raidal bearing	Incompatible with salt/corrosion
Shaft Coupling	Incompatible with salt/corrosion	0.3	4	1.2	Between sahft and ID of sleeve		**	Bushings for radial sleeve	Incompatible with salt/corrosion
Drive and Control System	Insufficient turndown ** time between restarts	0.3	4	1.2	Setup of VFD and fail safes is critical		**	Shaft Coupling	Incompatible with salt/corrosion
Monitoring system	Monitor: Vibration, Bearing temps, HP, Prsssure, Level gages	0.3	4	1.2	Critical to know how the pump is running as it is the heart of the system		5	Drive and Control System	Insufficient turndown ** time between restarts
Flow Meter	Monitoring system	0.3	4	1.2	Critical to keep receiver cool		**	Monitoring system	Monitor: Vibration, Bearing temps, HP, Prsssure,
Motor	Insufficient power	0.2	5	1.0	Damage to motor		**	Flow Meter	Monitoring system
Impeller/Pumphead/Volute	Incompatible with salt/corrosion	0.3	3	0.9	Material Selected must be designed for high corrosive salts		***	Freeze up in closed valve	
Column assembly	Insufficient strength at operating temperature	0.2	4	0.8	High vibration, binding of rotating assembly		1	Motor	Insufficient power
Mounting plate	Insufficient strength at operating temperature	0.2	4	0.8	Flexing of mounting causing leaks at discharge flange		4	Impeller/Pumphead/Volute	Incompatible with salt/corrosion
Fasteners and Gaskets for columns	Insufficient strength at operating temperature	0.2	4	0.8	High Vibration loss of head prssure of pump		**	Column assembly	Insufficient strength at operating temperature
Isolation Valves	Chemically incompatible w/salt	0.2	4	0.8			**	Mounting plate	Insufficient strength at operating temperature
Isolation Valves	Mechanically Unstable	0.2	4	0.8			**	Fasteners and Gaskets for columns	Insufficient strength at operating temperature
Impeller/Pumphead/Volute	Erosion	0.2	3	0.6	If any impurities are left in the salt after melting then the could be major problems with Erosion these p		8	Isolation Valves	Chemically incompatible w/salt
Head pressure	Insufficient head	0.2	3	0.6	Wrong speed from VFD		8	Isolation Valves	Mechanically Unstable
Flow	Insufficient flow	0.2	3	0.6	Blocked lines or valve		4	Impeller/Pumphead/Volute	Erosion
Shaft	Incompatible with salt/corrosion	0.1	2	0.2	Materials selected must be design for high temperature applications		***	Impeller/volute wear rings	Incompatible with salt/corrosion
Shaft	Insufficient strength at operating temperature	0.1	2	0.2	Material Selected must be designed for high temperature appplications		6	Head pressure	Insufficient head
Impeller/Pumphead/Volute	Insufficient strength at operating temperature	0.1	2	0.2	Materials selected must be design for high temperature applications		7	Flow	Insufficient flow
Motor	Not available			-			2	Shaft	Incompatible with salt/corrosion
Impeller/volute wear rings	Incompatible with salt/corrosion						2	Shaft	Insufficient strength at operating temperature
Insolubles in melted salt	High wear in bearings						4	Impeller/Pumphead/Volute	Insufficient strength at operating temperature
Isolation Valves	Availability						1	Motor	Not available
Freeze up in closed valve							8	Isolation Valves	Availability

Overviews & Research Progress by Topic 2 Teams - Pumps

3-5 Min. Presentations

- MIT, Flowserve ~ Dr. Henry Asegun
- Hayward Tyler ~ Keith Oldinski , Jeffry Belotii
- Powdermet and Sulzer Pumps ~ Joseph Hensel, Philippe Dupont
- Kevin Robb (ORNL) – PI for 300-kWth chloride salt test loop

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Gen3CSP
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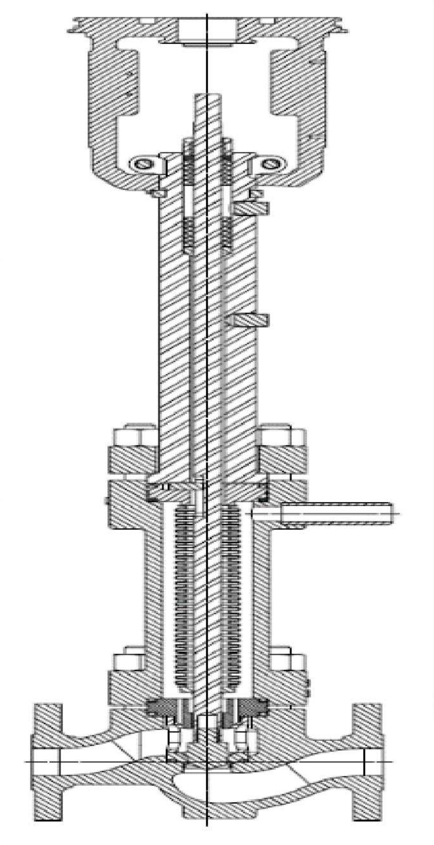
Gen 3 System – Valve Technical Challenges

- Several Types of Valves are required for test system
- Flow Control Valve (FCV)
- Isolation Valves
- Check Valve
- Technical Challenges
  - Materials corrosion
  - Thermal Mechanical Fatigue
  - Thermal management
    - Bonnet
    - Bellows
    - Valve Stem
  - Packing, gaskets and seals



Traditional Valve Design, Courtesy of Flowserve

Gen 3 System – Valve Technical Challenges (Dan Barth)

FEATURES & MODIFICATIONS

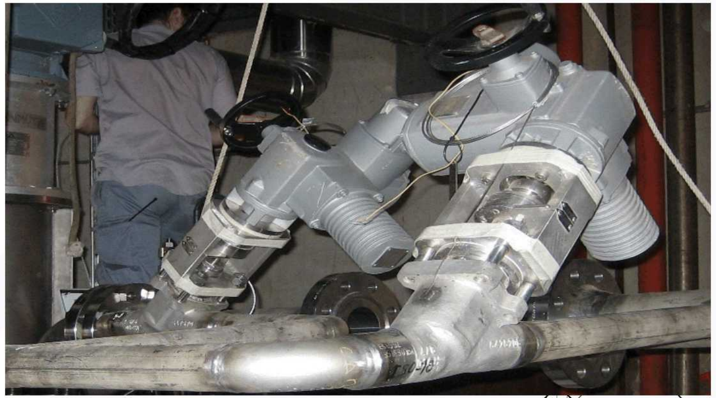
BODY:
- material: TBD
- all body connections welded
- upstream body extended to prevent thermal deformation of seat area during installation

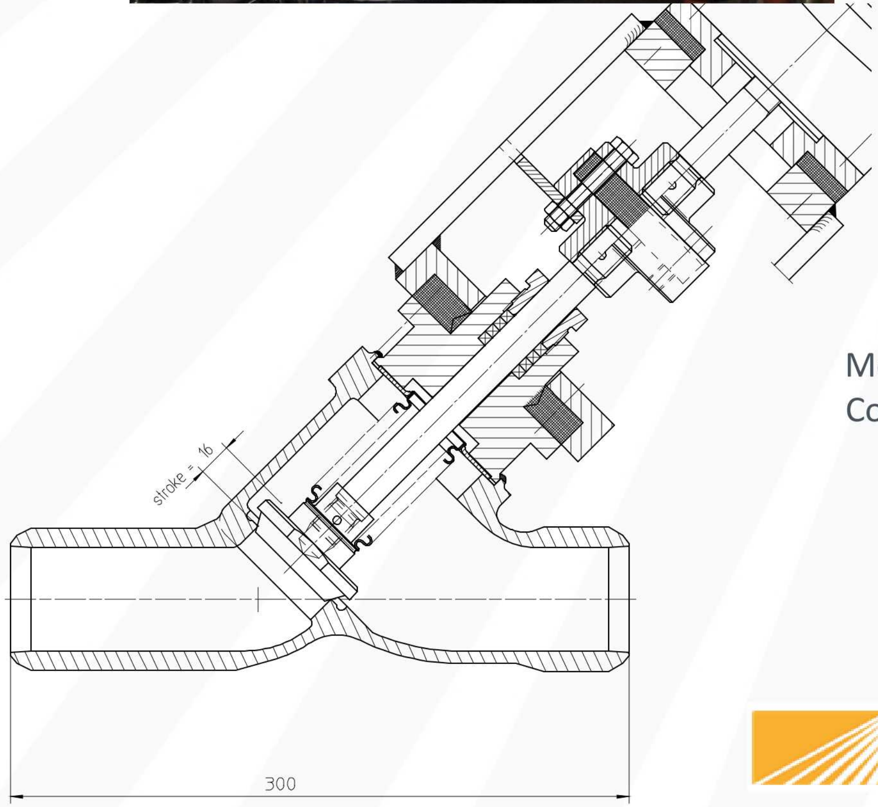
PLUG:
- material: TBD
  corresponding thermal exp. factor to bellows and hardness (240HB)

BELLOWS:
-Material: TBD
- pressure rating TBD
- weld-assembly of plug, bellows and base-plate carried out by manufacturer
- pressure testing of completed assembly carried out by manufacturer

STEM:
-Material : TBD
- double sealed by bellows and stuffing box

ACTUATOR AND SPINDLE:
thermally decoupled from valve body/stem
by high-strength insulating board
PROMAT MONOLUX 800
(classific. Temp. 800°C)

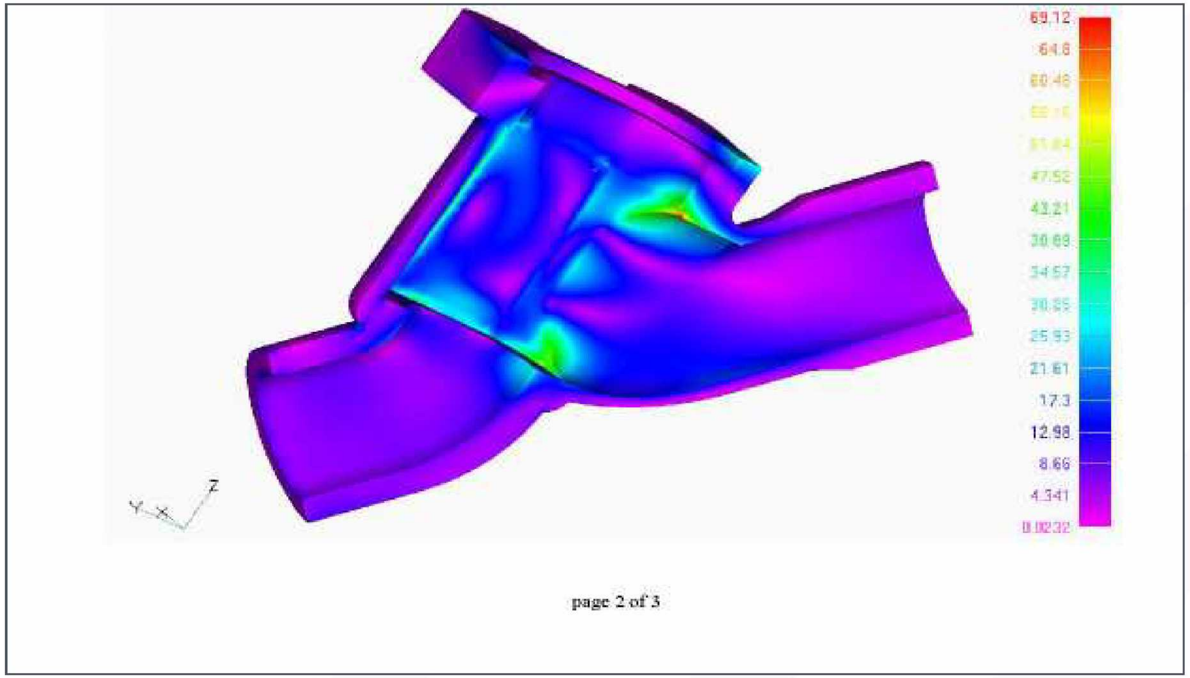




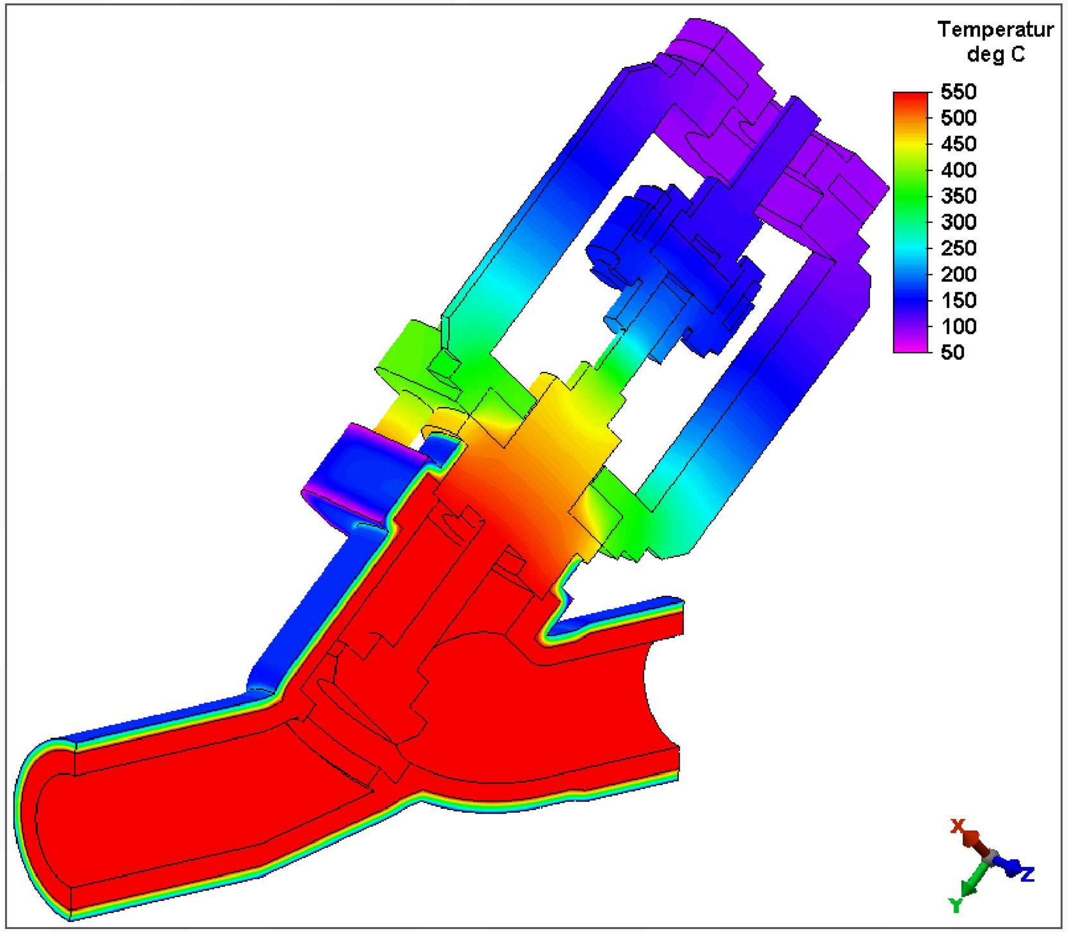
Molten salt Valve Design, Courtesy of Friatec Valves

Gen 3 System – Valve Technical Challenges (Dan Barth)

3D-Model & FE-Analysis



THERMAL CALCULATION



Gen 3 System – Valve Technical Challenges

Courtesy of Flowserve

Valve Specifications

- Example of Valves Specs Sheet on Right
- Valves needed per P&ID are Flow Control Valves
  - Typically Globe/Gate Valves, not Ball Valves
- Specific Valve Components Requiring R&D:
  - Bellows
  - Packing
  - Gaskets and Seals
  - Bonnet
  - Valve Stem
  - Thermal Management

Example:

PROJECT DATA	1	Tag Number	Rev.		3WSH10AA091	0	
	2	Service			SALTS TO HOT TANK		
	3	Location	P&ID		3WSH10BR101	AND1-SRPP-DG-0001	
	4	Pipe Size	Schedule	Insulation	C3D 12"	Sch. 20	YES
OPERATING CONDITIONS	5	Fluid	State		NITRATE SALTS	LIQUID	
	6	Inlet Pressure Max.	Norm.	Min.	2.29 barg	---	3.53 barg
	7	Outlet Pressure Max.	Norm.	Min.	0 barg	---	0 barg
	8	Temperature Max.	Norm.	Min.	386°C	---	386°C
	9	Flow rate Max.	Norm.	Min.	1491173 kg/h	---	322920 kg/h
	10	Pressure Drop Max.	Norm.	Min.	2.29 bar	---	3.53 bar
	11	Viscosity Oper. Conditions	Vapor Pressure		1.8 cP	---	
	12	Air Fail Position	Critical Pressure		CLOSE	---	
	13	Cp / Cv	Molecular Weight		---	---	
	14	Compressibility Factor	Density		---	1737 kg/m3	
	15	Cv required	Cv min allowed	Cv Valve	Note 1	Note 1	Note 1
	16	Rangeability	Admissible Noise		Note 1	< 85 dBA	
	17	Available Air Pressure	Design Pressure		7 barg	20.3 barg	
	18	Max Differential Pressure	Design Temperature		13.7 barg	400° C	
BODY	19	Type	Material		GLOBE	ASTM A-216 WCC	
	20	Size Port	Rating	Max. Temp.	Note 1 FULL	3 0 0 #	---
	21	Connections Size	Pressure	Finish	BW(Note 2) 12"	---	---
	22	Cooling fins	Bellows		NO	NO	
	23	Bonnet Type			EXTENDED		
TRIM	24	Valve Plug Material	Type		STELLITE	Note 1	
	25	Seat Type Material	Seat leak class		Note 1	STELLITE	CLASS IV
	26	Cage Material			Note 1	Note 1	
	27	Type of Packing	Material		Note 1	GARLOCK PBI	
	28	Flow Action to	Characteristic		OPEN	LINEAR	
	29	Trim Size			Note 1		
ACTUATOR	30	Type	Size		SPRING AND DIAPHRAGM	Note 1	
	31	Operating Fluid	Fail Position		AIR	CLOSE	
	32	Mechanical Travel Limit	Travel		---	---	
	33	Pneumatic Connections			1/4" NPT-H		
	34	Handwheel			YES		
POSITIONER	35	Type			ELECTRO-PNEUMATIC		
	36	Input Signal	Output Signal		4-20 mA (HART)	Note 1	
	37	Power Supply			24 V dc		
	38	Electrical Connections	Pneumatic Connections		1/2" N PT-H	1/4" N PT-H	
	39						
ACCESSORIES & REQUIREMENTS	40	Protection grade	Electric classification	Certified by	IP 65	—	—
	41	Regulating Filter	Manometers		YES	YES	
	42	Indication of Local Position			YES		
	43	Solenoid Valve	Power Supply		ASCO	230Vca	
	44	Limit Switches	Type		2 (Open / Close)	DPDT (2 A, 24 V dc)	
MANUFACTURER	45	Manufacturer			Note 1		
	46	Model			Note 1		
	47	Series N°			Note 1		
	48	S u p p l i e r			Note 1		
	49						
	50						

NOTES:
1- To be filled out by Manufacturer
2 - SPOOL EXTENDED 100 mm.OF A 106 Gr.C (ST) S/ANSI B 36.10 SIZE AND SCH ACCORDING TO PIPE
3 -

REVISION	DESCRIPTION	DATE	WRITTEN	APPROVED					
					WRITTEN	M.B.	27-07-06	UNIT	THERMAL STORAGE
0	Invitation to Tender	27-07-06	M.B.	ES	CHECKED	ES	27-07-06		
					APPROVED	JIL	27-07-06	PROJECT	Andasol-1 (P227295)

TITLE: DATA SHEETS

PNEUMATIC VALVES

RQ N° REV. 0 SHEET:1 OF 12 REV. 0

Overviews & Research Progress by Topic 2 Teams - Valves

- Massachusetts Institute of Technology

  Based on their use of low-cost novel refractory materials and processes to form these materials into the complex shapes needed to form pump and valve components, they will help ensure long life in these critical pieces of equipment in the molten salt loop.

- Further need for assistance?

  The valves in a molten salt system are one of the most critical pieces of equipment in the loop. The pump is the heart of the system but with out the valves, we cannot operate the system efficiently. Controlling the molten salt flow during startup, daily operations and shut down will all be effected by the valves in the system.

Contents


Gen3CSP
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Work Going Forward

- Topic 1&2 standing monthly meetings to touch base on R&D progress
  - Topic 1 information pass downs pertaining to:
    - Materials selections
    - P&ID System Development
    - Salt Chemistry selections and alloy/welding research updates
    - Integration discussions
  - Topic 2 Research progress
    - Milestone updates
    - Updated results
    - Technical, administrative or schedule challenges

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- Craig Turchi (National Renewable Energy Labs) - craig.turchi@nrel.gov, 303-384-7565
- Ken Armijo (Sandia National Labs) – kmarmij@sandia.gov, 505-284-3425

Questions?

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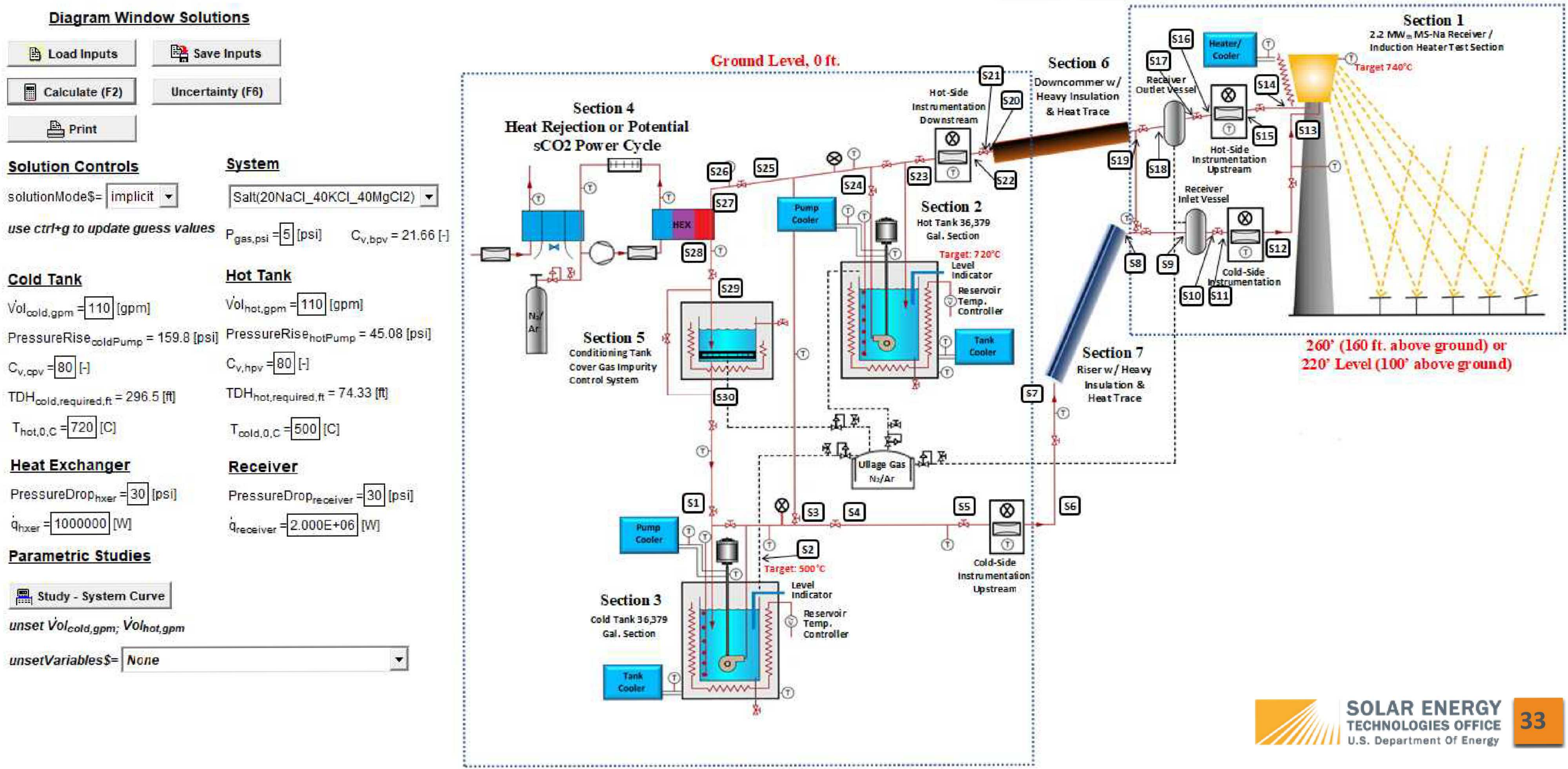
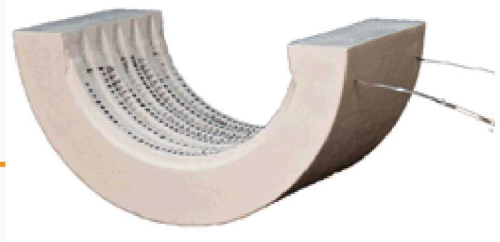
Extra Slides

EES System Model



Task 1.3: Piping, Heat Trace & System Layout



- Team reviewed three possible pipe pre-heating systems and had discussions with multiple manufacturers on system limitations and possibilities of manufacturers developing higher-temperature rated systems.
- MI cable is capable of pre-heating the pipe to 450°C however the cable has a maximum temperature exposure of 590°C.
- Impedance heating system is capable for preheating pipe to 450°C and can be exposed to temperatures exceeding 750°C.
  - Valves and flowmeters must be completely isolated from the electrically energized piping; otherwise valves and flowmeters will not function.
  - Isolation requires flanged connections on valve and flowmeters with an electrical insulator between the flanges and flange bolts.
  - However, flanged fittings are not possible due to salt wicking effects.